1978

Relative Capital Accumulation In The United States

James D. Adams
Iowa State University

Relative Capital Accumulation In The United States

Abstract
Since the publication of Keynes' General Theory economists have treated the demand for particular forms of wealth as a problem in portfolio balance. The later development of the Human Capital approach essentially elaborated on this analysis by extending the choice of forms in which to hold wealth, and also stimulated interest in the mechanism of parental finance of the human capital investments (Becker, 1967) For this reason, human capital models are antecedents of intergenerational models of the demand for wealth and the composition of wealth.

Disciplines
Economic Theory | Growth and Development | Income Distribution | Statistical Models

RELATIVE CAPITAL ACCUMULATION

IN THE UNITED STATES

by

James D. Adams

No. 71

I. Introduction

Since the publication of Keynes' General Theory economists have treated the demand for particular forms of wealth as a problem in portfolio balance. The later development of the Human Capital approach essentially elaborated on this analysis by extending the choice of forms in which to hold wealth, and also stimulated interest in the mechanism of parental finance of the human capital investments (Becker, 1967).1/ For this reason, human capital models are antecedents of intergenerational models of the demand for wealth and the composition of wealth.

In the more recent, intergenerational models, the demand for wealth is placed in a family context which stresses the passing of wealth to future generations as well as more conventional savings motives. 2/ For example, positive saving over the life cycle, defined as a real net increase in the terminal wealth of heads of households over their endowed wealth, is traced to family affections through a bequest motive rather than to chance. When the family size or fertility decision is incorporated into the process of household utility maximization, the choice between numbers of the next generation and their per capita wealth is also defined. A link is thereby forged between positive savings over the life cycle and economic growth, under which a real net increase in per capita wealth takes place.

This paper develops an analysis of the determination of wealth composition for any cohort or generation - whether to hold wealth in human or physical form - and examines the effect of changes in the rate of exogenous economic growth on the composition of wealth. These adjustments in portfolio composition are assumed to be accomplished partly through saving and partly through intergenerational transfers. It is clear that wealth is held in view of future incomes of the individual and the circumstances of his children, which are affected by growth and technical change. Among other propositions, I show that neutral economic growth has non-neutral effects on relative capital accumulation, where relative refers to comparative size of human and physical capital; and I attempt to verify this proposition empirically.

Organization of the paper is as follows. In Section II, I develop a model of the optimal level and composition of wealth holding on the part of families; I then introduce economic growth, and examine the comparative statics effects of growth on wealth holding. Section III discusses the transition between theoretical constructs and their empirical counterparts, followed by Section IV, in which the empirical results are presented and interpreted. A brief concluding section summarizes the findings.

II. Theoretical Considerations

A. Demand for Wealth by an Individual Household

Wealth accumulation is motivated by the head's objective of maximizing his intertemporal utility function. Therefore, he holds assets and human capital in a proportion which maximizes the value of his wealth, subject to an endowment constraint. Our objective is to show that he transfers forms of wealth to his children and the next generation in a way which also maximizes their attained wealth for a given expenditure on the transfers. This determines the wealth composition of the next generation or cohort.

The head's utility function is assumed to depend upon his present and future consumption (C_j and $\overline{C}_j$), per capita utility and thus per capita expenditures of his children (C^*_{j+1}), and the number of children n_{j+1}.[3/] In this notation j is an index for the current generation, j+1 is for children or the next generation, barred variables indicate the future, unbarred variables the present, and the asterisk over expenditures of the next generation stresses the inclusion of expenditures on others as well as on their own consumption.

The head's multiperiod consumption enters as an aggregate, V_j, into his utility, while per capita expenditures of his children enter through their utility function $V_{j+1} = V_{j+1}(C^*_{j+1})$. According to this discussion the head's utility function, U_j, can be written as

$$U_j = U_j \; [V_j \; (C_j, \bar{C}_j), \; n_{j+1}, \; V_{j+1} \; (C^*_{j+1})] \tag{1}$$

for related specifications see Adams (1976) and Becker and Tomes (1976).[4/] Notice that entering the number of children in the head's utility incorporates an endogenous fertility decision into the model.

Let us next consider the wealth constraints which are relevant to the head of the household. His wealth, W_j, is spent on the discounted value of his own consumption and total transfers which he makes to the next generation, which are the product of per capita transfers, g_{j+1}, and the number of children n_{j+1}.[5/] Therefore the head's wealth constraint is

$$W_j = C_j + \frac{1}{1+r} \bar{C}_j + n_{j+1} \; g_{n+1}, \tag{2}$$

where r is the rate of interest. The portfolio aspect of the model is introduced by assuming that wealth of the present generation as well as transfers to the next generation can assume the form of human capital as well as assets.

Treating W_j as already maximized with respect to its composition, composition of the gross transfers g_{j+1} is determined by a utility maximizing process. Let per capita transfers of human capital be h_{j+1} and per capita asset transfers be a_{j+1}, where units in each case are defined to be worth $1 when received. However, it may cost more than $1 to transfer the units. In the case of assets, gift and estate taxes and transactions costs cause gross transfers to exceed net; in the case of human capital, rising direct and foregone earnings costs eventually cause the same result, assuming that accumulation of human capital is subject to diminishing returns. Defining transfer prices for assets and human capital of P_a and P_h respectively, the equation for gross transfers reduces to the sum of expenditures upon components, or

$$g_{j+1} = P_a \, a_{j+1} + P_h \, h_{j+1}. \tag{3}$$

Gross transfers exceed net transfers t_{j+1}, defined as the sum of the components in values when received, or

$$t_{j+1} = a_{j+1} + h_{j+1}, \tag{4}$$

where it will be recalled that a_{j+1} and h_{j+1} are scaled in $1 units.

Costs associated with the transfers may depend on the size of the transfers. However, costs are expected to behave differently for assets and human capital. With the exception of progressive transfer taxes, which are clearly unimportant in a representative model, per unit costs of transferring the assets appear to be independent of the size of transfer. Thus

P_a is assumed to be constant throughout this paper.

The situation is very different for human capital transfers. As their per capita level rises, they are subject to rising marginal costs, because they are produced under diminishing returns. Diminishing returns take place because an important input, ability or capacity of the individual to acquire the capital, is held constant even as other educational inputs are increased (Becker, 1967; Blinder, 1976). Therefore, the transfer price of human capital is assumed to rise with per capita amounts, or $P_h = P_h(h_{j+1})$, and $dP_h/dh_{j+1} > 0$. Marginal costs MC_h exceed the transfer price.[6/]

Wealth of the next generation, W_{j+1}, is the sum of endowed wealth, e_{j+1}, and net transfers, t_{j+1}, yielding the budget constraint

$$W_{j+1} = e_{j+1} + t_{j+1} = C^*_{j+1}. \tag{5}$$

Equation (1) defining the head's utility function, (2) representing the current generation's wealth constraint, (3) and (4) defining the portfolio composition of wealth transfers, and (5) representing the per capita wealth constraint of the next generation, summarize the utility maximizing problem.[7/] The model summarized by equations (1) through (5) yields the first order conditions

$$\frac{\partial U_j}{\partial V_j}\ \frac{\partial V_j}{\partial C_j} - \lambda = 0 \tag{6}$$

$$\frac{\partial U_j}{\partial V_j}\ \frac{\partial V_j}{\partial C_j} - \frac{\lambda}{1+r} = 0 \tag{7}$$

$$\frac{\partial U_j}{\partial V_{j+1}}\ \frac{\partial V_{j+1}}{\partial C^*_{j+1}} - \lambda MC_h n_{j+1} = 0 \tag{8}$$

$$\frac{\partial U_j}{\partial V_{j+1}} \frac{\partial V_{j+1}}{\partial C^*_{j+1}} - \lambda P_a n_{j+1} \leq 0 \tag{9}$$

$$\frac{\partial U_j}{\partial n_{j+1}} - \lambda g_{j+1} = 0 \tag{10}$$

$$W_j - C_j - \frac{1}{1+r} \overline{C}_j - n_{j+1} g_{j+1} = 0 . \tag{11}$$

Conditions (8) and (9) are optimality conditions for the levels of human capital and asset transfers respectively, which are alternative means for increasing per capita consumption and wealth of children. It is implicitly assumed that positive transfers of human capital are always attained.[8/] Equation (10) is the optimality condition for the number of children. Since this is a quantity-quality model (Houthakker, 1952; Becker and Lewis, 1973), numbers of children are a cost of raising the level of per capita consumption in (8) and (9), while per capita transfers are a cost of increasing the number of children in (10).

Two solutions to the portfolio composition of transfers are generated according to this approach. The current generation transfers only human capital, given sufficiently small wealth W_j so that the level of h_{j+1} yields the result $MC_h < P_a$, and $a_{j+1} = 0$, since the gains to transferring either form of wealth are identical, and hence they are perfect substitutes, as an inspection of (8) and (9) reveals. In this case, (9) is a strict inequality. The second solution occurs when W_j and h_{j+1} are sufficiently large so that $MC_h = P_a$ and $a_{j+1} > 0$ (Becker, 1967).

Under the first solution, increases in the present generation's wealth increase only per capita human capital transfers, as long as these are below some critical level at which $MC_h = P_a$. Under the second solution, increases in the head's wealth raise only per capita asset transfers.

B. Growth Aspects

The representative family of the preceding section exists in an economy in which consumption goods, physical capital, and human capital are produced using services of physical capital, raw labor, and human capital. This three factor economy is the counterpart to the two asset model of the head's portfolio already discussed.

It is not possible to specify the nature of technical change *a priori* in terms of its implied effects on optimal factor combinations, as Samuelson (1965) has shown in his model of the benefits of innovation. We would expect the relative rates of augmentation of the factors to be optimizing, in the sense that benefits would be maximized for a given expenditure, and the expenditures on research and development projects to be carried to that point where research and development projects yield comparable rates of return to more conventional projects. Optimizing development of innovations would be based on their expected benefits and costs, and fluctuations in the rate of production of innovations could presumably be explained in terms of variations in the costs and benefits. It has been suggested that empirically, changes in the benefits explain most of the fluctuations in innovation rates (Schmookler, 1966). Since there appear to be no compelling reasons to assume either neutrality or non-neutrality of factor augmentation, I assume as an approximation that growth is commodity-neutral and therefore leaves relative prices of consumer and investment goods unchanged, apart from a dynamic effect discussed below.

It is useful to incorporate a non-neutral effect of growth for which there is accumulating evidence (Schultz, 1975). This effect depends on a complementary relationship between human capital and the rate of technical change (known as the Allocative Hypothesis) for its validity. According to the Allocative Hypothesis, available technology is adopted more rapidly, the larger is human capital. In this view, part of the return to human capital lies in its ability to capture the profits of disequilibrium; therefore, the greater is the rate of technical change, the greater is the return to human capital, since there is inherently more disequilibrium to which allocative skills can be applied (Nelson and Phelps, 1964). [9/] We would expect technical change to be biased toward holding wealth in the form of human capital even if it is factor neutral, because of the allocative return to the capital.

Other effects of an increase in the rate of technical change would be a rise in the rate of interest and an increase in future incomes relative to the present. The rate of interest would tend to increase because the marginal productivity of capital would increase while the price of capital would tend to remain the same in terms of consumer goods.[10/] Future incomes would increase because more commodities of all kinds could be produced.

C. Portfolio Adjustment to Changes in the Rate of Growth

An increase in the rate of economic growth under the conditions specified in the preceding section would raise the desired stock of human capital relative to assets and therefore physical capital. This portfolio adjustment occurs for several reasons. First, the enhanced relative marginal productivity of human capital implies that the marginal cost of human capital decreases, since a smaller expenditure could then purchase the same income stream as could a larger expenditure before. This provides an incentive even for the present generation to retrain and alter the composition of its own wealth in favor of human capital, but it does so especially for the composition of intergenerational transfers, in the case of either solution discussed in Section II. A.

In the case of the first solution, where $a_{j+1} = 0$, since MC_h is inversely related to the rate of growth (see footnote 9), desired consumption and human capital transfers to the next generation would rise if the fall in MC_h were the only effect. In the case of the second solution, where $a_{j+1} > 0$ and $MC_h = P_a$, the fact that MC_h is reduced raises h_{j+1} and lowers a_{j+1} by the same amount. Thus if growth lowers MC_h alone, human capital transfers rise absolutely and asset transfers fall absolutely. Desired human capital stocks rise absolutely for the two generations combined and the stock of physical capital falls.

A full analysis is not as simple as the preceding discussion suggests, because there are wealth effects as well as price effects of an increase in growth. Future incomes of both generations increase, implying a decrease in the overall accumulation of capital and current consumption rises relative to unchanged current income. The reduction in accumulation causes the achieved rate of growth to lie below the exogenous rate of technical change.

If per capita intergenerational transfers (t_{j+1}) decrease, there is also a wealth effect of economic growth which favors a rise in the share of human capital in all wealth. To see this, recall that for families with sufficiently small wealth, $a_{j+1} = 0$, and transfers are entirely in human capital; while for families with larger wealth $a_{j+1} > 0$, and transfers are partly in assets. Any decline in transfers for less wealthy families takes place only in human capital, and the share of human capital in transfers for these families remains at 100%. For the wealthier families, the reduction in transfers takes place only in assets, raising the share of human capital in their transfers, and in the economy as a whole.[11/]

The effect of a rise in the rate of growth on net transfers is

$$\frac{\partial t_{j+1}}{\partial g} = \frac{\partial C^*_{j+1}}{\partial SW_j} \left[(1+\Theta)\, P_a\, n_{j+1} \frac{\partial e_{j+1}}{\partial g} \right] - \frac{\partial e_{j+1}}{\partial g}, \tag{12}$$

where $\frac{\partial C^*_{j+1}}{\partial SW_j}$ is the effect of an increase in the head's combined wealth on the next generation's (per capita) consumption, the term in brackets is the increase in combined wealth, Θ is the ratio of the increase in the head's wealth to the increase in the next generation's wealth, and the term subtracted is the endowment (see Appendix A). If Θ were close to zero, equation (12) would be negative, because the first term is then the (per capita) wealth effect on the next generation's expenditures, while the second term is the (per capita) wealth effect itself, which must be larger if other consumption is normal.[12/] Since we would argue that Θ is small, or far less than one, we would also argue that there is a wealth effect in addition to the price effect of growth favoring a larger share of human capital in accumulation and the total capital stock.[13/]

Since we have shown a certain price effect and a likely wealth effect of an increase in the rate of technical change causing a rise in relative human capital accumulation, and also demonstrate a partial decline in the overall accumulation in response to greater technical change, we would like to close the theoretical discussion by drawing implications for the effects on the level of asset accumulation or saving and human capital accumulation. The level of saving decreases because overall accumulation falls and the share of saving in accumulation declines, while investments in human capital increase (decrease) if the rise in their share in accumulation exceeds (is less than) the decline in the overall level of accumulation.

III. Transition to Empirical Analsyis

Estimates of the stock of various kinds of human capital are scarce. However, estimates of annual investments in education, a principal form of human capital, can be constructed; presumably, a rise in the desired stock of human capital is reflected in a rise in human capital investments, as the Partial Adjustment framework suggests. Implications of the preceding section are therefore tested using estimated human capital investments and data on personal savings. This section describes the variables used in the analysis and the empirical strategy.

Time series data were collected for the period 1930-1970. Basic dependent variables used in the regressions were personal savings and a measure of educational expenditures, or a variable derived from them. All variables were deflated by a price index and divided by the number of family units, since the family was the unit of analysis in the theoretical model. Appendix B describes sources and methods of data construction in greater detail. Personal savings consists of savings out of Disposable Personal Income. Educational expenditures per family were constructed using a technique developed by Schultz (1971). Direct expenditures for grade school, high school, and college were combined after netting out non-education expenditures and adding in implicit interest and depreciation. Indirect expenditures or foregone earnings per year were computed on the assumption that the loss in earnings was zero for grade school pupils, equivalent to 11 weeks of average earnings in manufacturing per high school student, and equivalent to 25 weeks of average earnings in manufacturing per college or university student.[14/] Per student expenditures were then multiplied by enrollments and summed. Combined direct and indirect expenditures were divided by the number of family units and divided by an educational cost index. The latter was a simple Laspeyres price index with four weights, revised once every decade, for wage costs of elementary and secondary teachers and support staff, college teachers and administrative personnel, maintenance, and foregone earnings.[15/] Charts 1 and 2 show the time path of the constructed real educational expenditures and personal savings per family. The behavior of educational expenditures reveals irregular movements in the 1930's, a decline during the Second World War as manpower was diverted out of the schools, and a sharp upward trend beginning in the mid 1950's. The real expenditures more than doubled during the period. The series of real personal savings shows a gradual upward trend, interrupted as expected by cyclical phenomena and the increase in wartime savings.

Charts 3 through 6 graph the time paths of the major independent variables used in the empirical work. As measures of the rate of technical change, I used number of patents issued for the entire period, and deflated Federal Research and Development Expenditures for the Postwar period (1947-70). Number of patents issued in principle is a superior measure, because it represents the output of research rather than input, and because the number of important inventions out of a large number of patents presumably does not change systematically over time. In practice, an objection arises, because the fraction of inventions patented appears to have declined over the course of the sample period. Schmookler (1962) attributes this trend to changes in the staffing of the Patent Office and increased delays in issuances; a rising

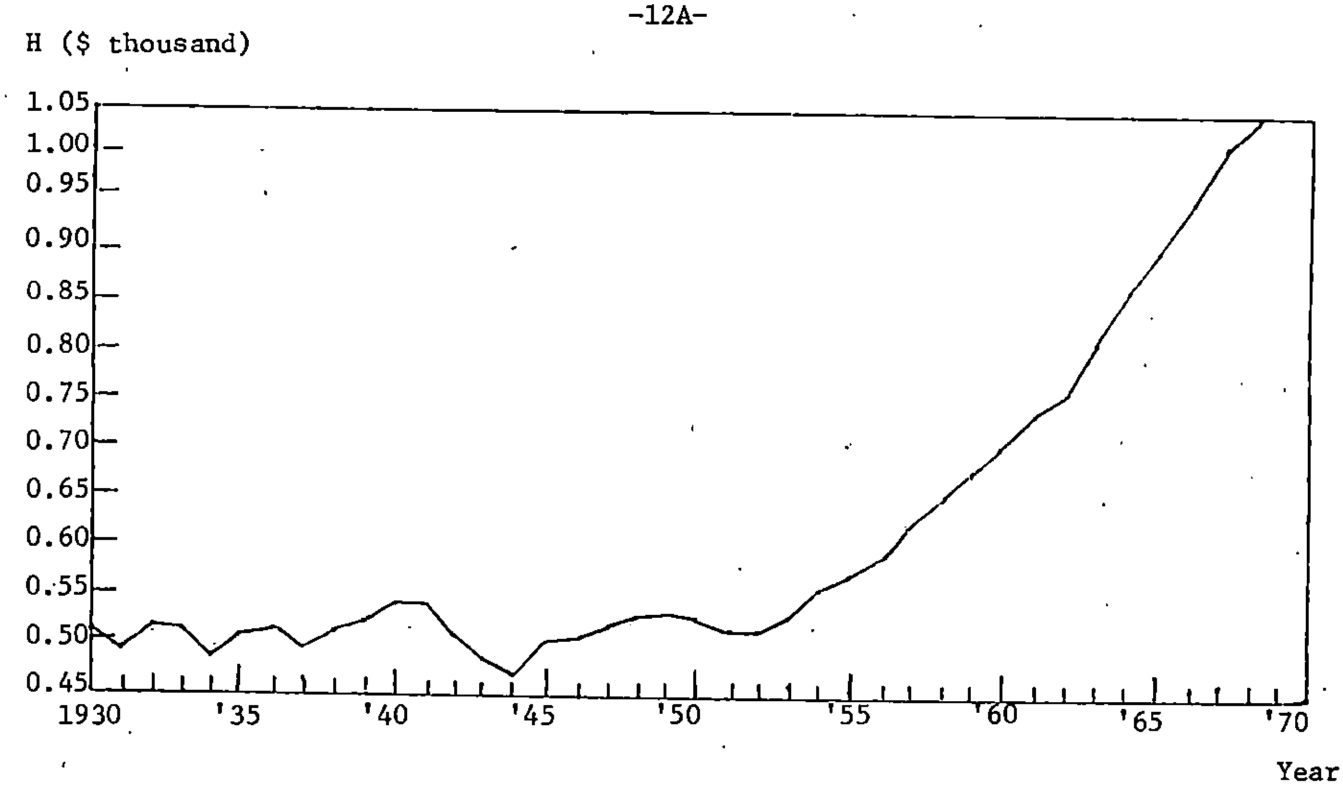

Chart 1 - Educational
Expenditures per Family (in 1958 $)

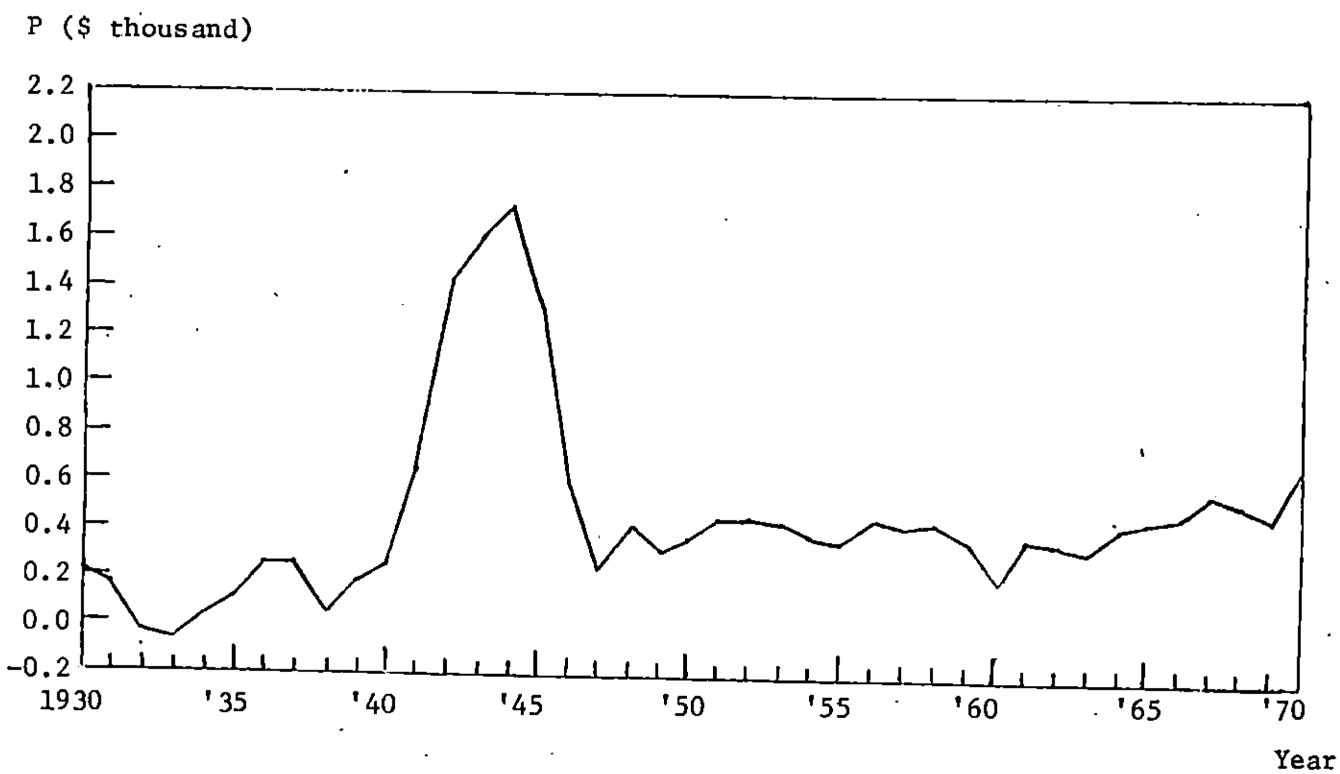

Chart 2 - Personal
Savings per Family (in 1958 $)

share of the Federal Government in innovations, for whom there is a lower propensity to seek patents; a lesser tendency to seek patents by firms because of increased court invalidations; and to a shift towards headstarts as opposed to patents due to a rising rate of obsolescence on inventions. Federal research and development expenditures include all governmental expenditures on research, yet they do not measure the output of the research itself, nor do they include research and development expenditures of the firm. Charts 3 and 4 graph these innovation measures. Patents issued (Chart 3) show considerable variability, sinking sharply during World War II, and after the Korean War, though the overall trend is upward. Federal Research and Development expenditures rise sharply, with the exception of a slight downturn in the mid 1950's and a more important decline at the close of the 1960's.

The incentive to make investments in schooling per family and perhaps also to save rises with the number of children; I use cumulative births per woman aged 44 to 49.[16/] Chart 5 depicts the U-shaped pattern of this variable, which reaches a minimum in the mid 1950's.

Since income of the family raises educational expenditures, I enter Disposable Personal Income per family among the regressors. Chart 6 shows a marked rise in income during the War, when there was an apparent rightward shift in labor supply. Income per family increases 60% over the period.

IV. Empirical Findings

Regressions are first run separately using measures of educational expenditures and personal savings as the dependent variables. Three educational variables are employed: expenditures inclusive of foregone earnings, but adjusted downward by the unemployment rate (H); expenditures inclusive of foregone earnings, but not adjusted for unemployment (HA); and direct

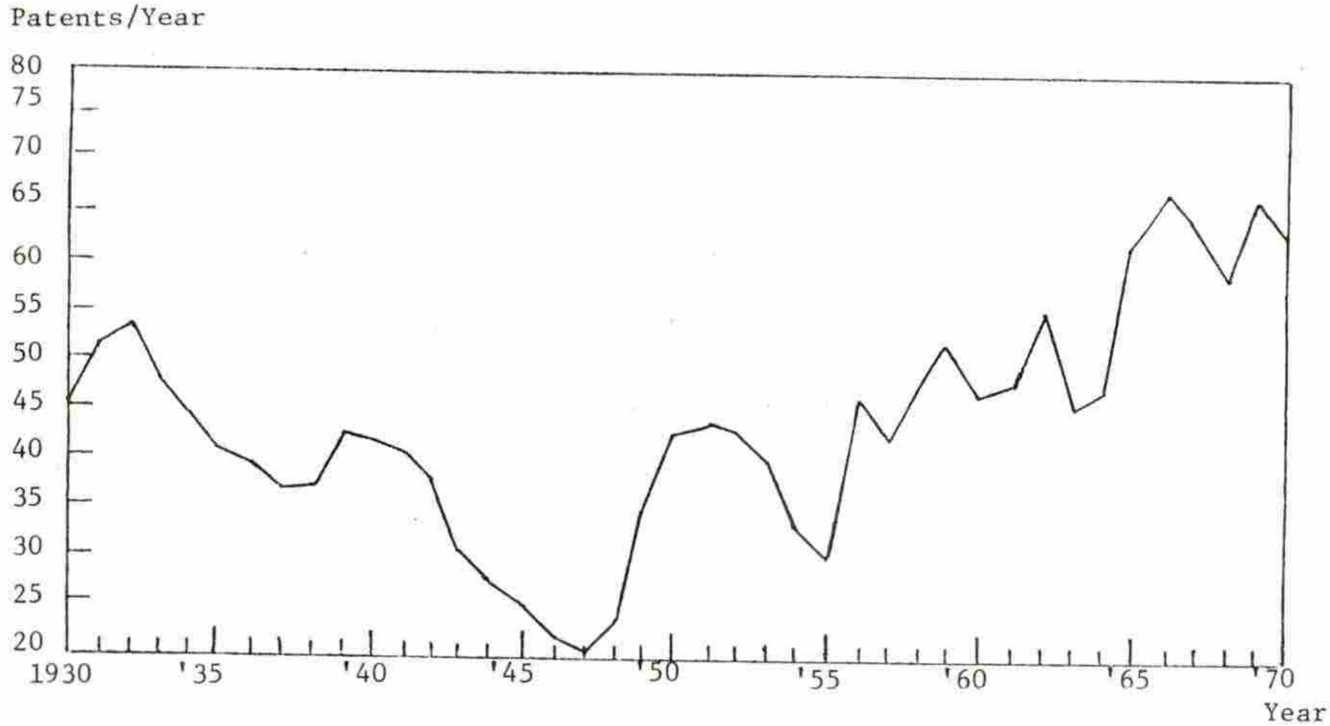

Chart 3 - Patents Issued
per Year (in thousands)

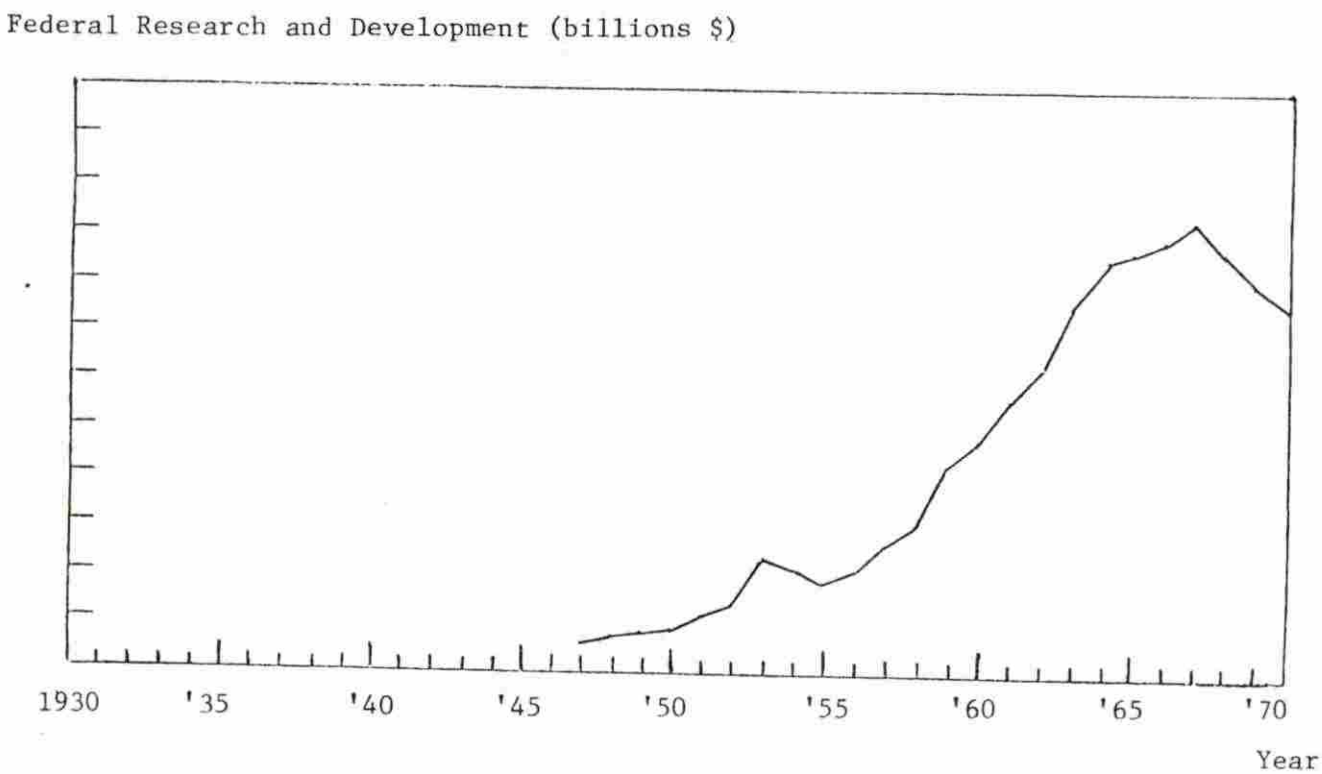

Chart 4 - Federal
Research and Development Expenditures (in 1958 $)

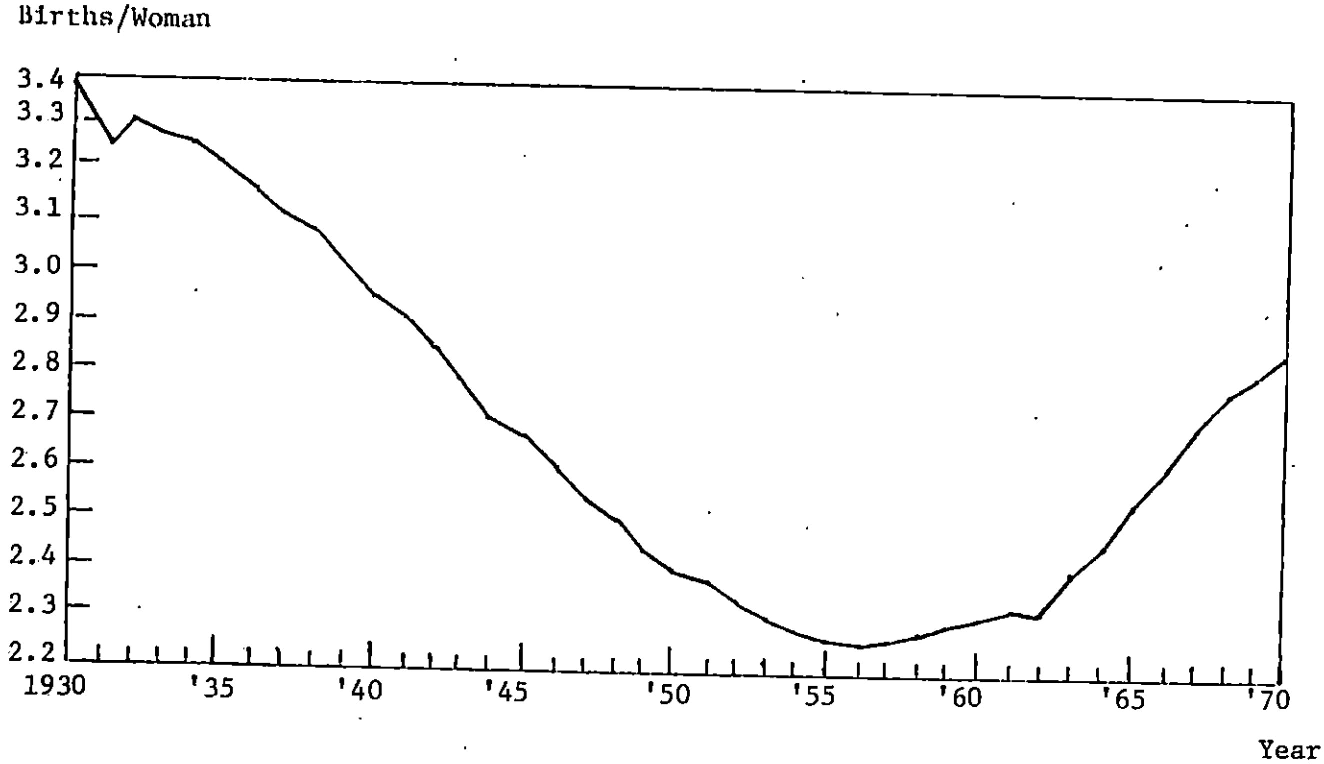

Chart 5 - Cumulative
Birth Rates per Woman Aged 45-49

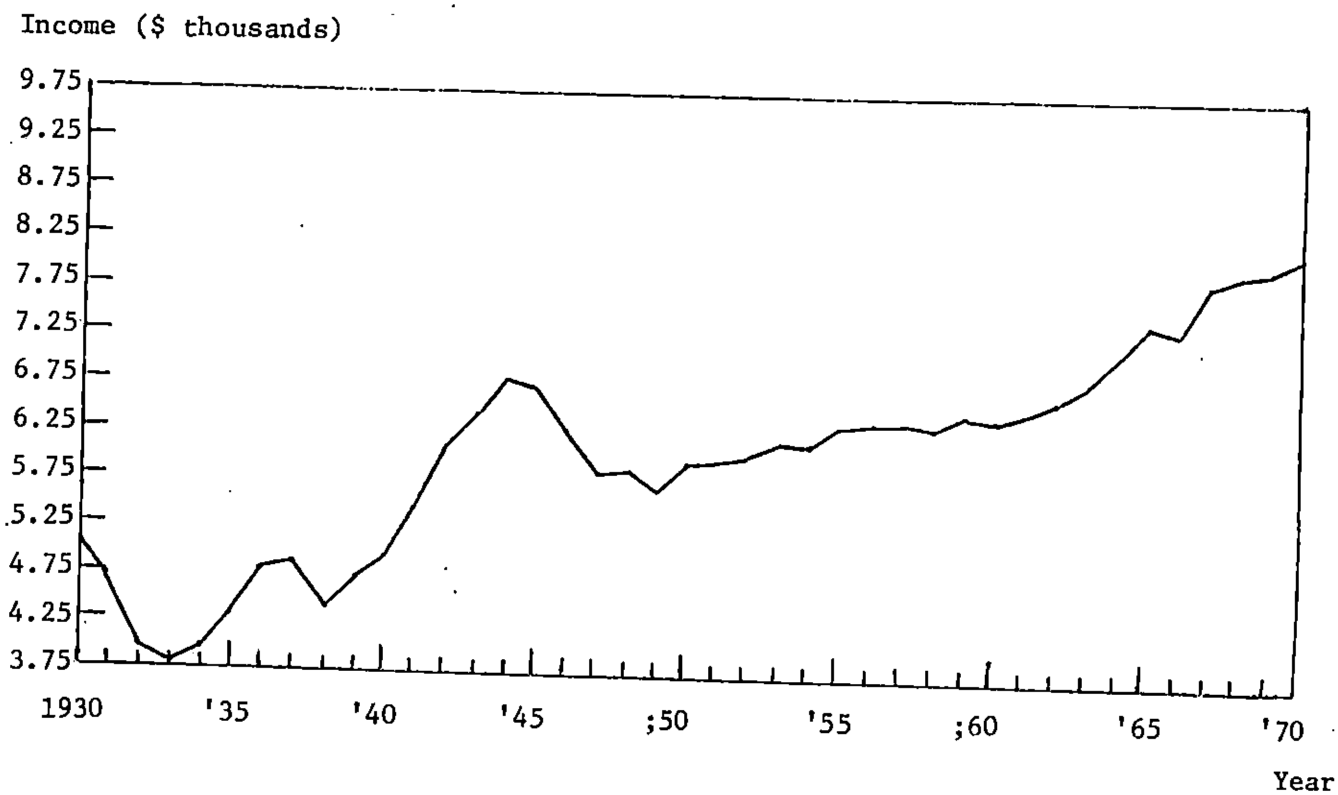

Chart 6 - Disposable
Personal Income per Family (in 1958 $)

expenditures alone (DH).[17/] In the case of H and HA, a comparison between direct cyclical adjustment of the educational expenditures (H) and an indirect adjustment by inclusion of the unemployment rate among the regressors (HA) seems useful. In the case of DH, it is interesting to search for potential differences in cyclical effects on the direct expenditures alone in contrast to total expenditures, since direct expenditures are financed out of current income or assets. Personal savings per family are the sole measure of asset accumulation.

Different sets of independent variables are used in regressions run for the entire period (1930-70) than for the postwar era alone (1947-70). A different measure of the rate of innovation, federal research and development expenditures (FRD) are used for the postwar era, partly because data only become available starting in 1947, and partly because the data on patent issuances have been asserted to be unreliable after the war (Schmookler, 1962). [18/] Number of patents issued is the innovation measure used for the entire period. The remaining difference in the set of regressors is a wartime dummy included because of war-induced shifts in education and personal savings. In the case of either innovation measure, we would expect that greater innovation would have a less negative and conceivably positive effect on educational expenditures, but a negative effect upon savings.

A set of variables common to both periods is also entered. Since incentives to acquire human capital and perhaps to save rise with family size, I include the cumulative birth rate (BCUML), expecting a positive coefficient. Current and lagged disposable income per family (YPF and YPF_{-1}) are included to capture household resources. The sum of the income coefficients is taken as an approximation to the effect of a permanent increase in income either on education or savings. Finally, the adult unemployment rate UNEMP is included in the HA regressions to account for cyclical influences.

Results are shown in Table 1. Equations 1.1 through 1.4 summarize findings for the entire period. Patent issuances increase human capital accumulation significantly in most cases, though the coefficient for NPATS in 1.2 is not quite significant. Also, cumulative births raise human capital accumulation, while current and lagged income both raise expenditures in most cases, though the effect of lagged income is never significant. The implied marginal propensities are 0.142, 0.193, and 0.083 in 1.1, 1.2, and 1.3 respectively. It is interesting to note that an increase of UNEMP by one percent raises human capital accumulation by 0.018 in equation 1.2, implying a countercyclical pattern. Finally the wartime dummy significantly decreases accumulation, signifying withdrawal of enrollment from high schools and universities.

The single equation for savings (P) shows a negative but insignificant effect of NPATS; the insignificance is contrary to expectation. Cumulative births do not influence P significantly, while, though the joint impact of higher current and lagged income is to raise savings, lagged income lowers savings, which squares with the notion that transitory increases in income raise savings more than permanent increases do; thus while the current year effect of a one unit increase is 0.402, the joint effect is only 0.153 and quite similar to marginal propensities to save implied by earlier consumption studies.[19]

Figures 1 and 2 graph actual versus predicted values for H and P which are implied by equations 1.1 and 1.4 respectively. Predicted values track actual ones with reasonable accuracy, with the exception of war years, as

TABLE 1

Educational Expenditure and Personal Savings Functions

(Standard Errors in Parentheses)

Eq.	Dep. Var.	Period	W	NPATS	FRD	BCUML	YPF	YPF_{-1}	UNEMP	CONST.	R^2	S.E.E.	D.W.
1.1	H^a	1930-70	-0.120	0.004		0.163	0.102	0.040		-0.809	0.879	0.044	1.384
			(0.033)	(0.001)		(0.046)	(0.031)	(0.030)		(0.169)			
1.2	HA	1930-70	-0.104	0.002		0.093	0.201	-0.008	0.018	-0.949	0.904	0.040	1.221
			(0.030)	(0.001)		(0.047)	(0.040)	(0.031)	(0.005)	(0.159)			
1.3	DH^c	1930-70	-0.077	0.003		0.090	0.060	0.023		-0.482	0.895	0.024	1.452
			(0.018)	(0.001)		(0.026)	(0.017)	(0.017)		(0.095)			
1.4	P	1930-70	0.722	-0.005		0.058	0.402	-0.249		-0.529	0.842	0.169	1.589
			(0.106)	(0.004)		(0.123)	(0.109)	(0.104)		(0.443)			
1.5	H^d	1947-70			0.015	0.122	0.085	0.067		-0.681	0.973	0.020	1.131
					(0.004)	(0.071)	(0.030)	(0.029)		(0.118)			
1.6	HA^e	1947-70			0.012	0.140	0.111	0.059	0.019	-0.909	0.993	0.016	1.458
					(0.002)	(0.043)	(0.027	(0.024)	(0.004)	(0.090)			
1.7	DH^f	1947-70			0.008	-0.003	0.064	0.045		-0.353	0.964	0.014	1.177
					(0.003)	(0.051)	(0.021)	(0.020)		(0.085)			
1.8	P	1947-70			-0.023	-0.034	0.357	-0.152		-0.717	0.744	0.051	2.098
					(0.006)	(0.110)	(0.085)	(0.082)		(0.197)			

Table 1 con't.

Notes: NPATS = number of patents issued in thousands; FRD = Federal Research and Development Expenditures in billions of dollars; YPF = current disposable income per family, in thousands of dollars; YPF_{-1} = lagged disposable income; and UNEMP = the adult unemployment rate in percentage form.

Equations with superscript letters adjusted for first order autocorrelation using Cochran-Orcutt method, where ρ = first order autocorrelation coefficient. [a] $\rho = 0.4035$ [b] $\rho = 0.4095$ [c] $\rho = 0.4185$ [d] $\rho = 0.5224$ [e] $\rho = 0.2291$ [f] $\rho = 0.5377$.

TABLE 2

Relative Accumulation Functions
(Standard Errors in Parentheses)

Eq.	Dep. Var.	Period	W	NPATS	FRD	BCUML	YPF	YPF_{-1}	UNEMP	CONST.	R^2	S.E.E.	D.W.
2.1	R	1930-70	1.610	-0.015		-0.036	0.689	-0.522		0.261	0.805	0.397	1.484
			(0.250)	(0.008)		(0.290)	(0.256)	(0.244)		(1.042)			
2.2	DC	1930-70	0.868	-0.009		-0.121	0.274	-0.266		0.352	0.807	0.207	1.458
			(0.130)	(0.004)		(0.151)	(0.134)	(0.127)		(0.544)			
2.3	R	1947-70			-0.049	-0.087	0.555	-0.390		0.014	0.667	0.090	1.701
					(0.011)	(0.194)	(0.150)	(0.145)		(0.350)			
2.4	RA	1947-70			-0.038	-0.181	0.436	-0.316	-0.044	0.672	0.742	0.081	2.204
					(0.011)	(0.179)	(0.143)	(0.133)	(0.018)	(0.423)			
2.5	DC	1947-70			-0.039	-0.131	0.303	-0.250		-0.094	0.886	0.058	1.736
					(0.007)	(0.126)	(0.097)	(0.094)		(0.226)			
2.6	DCA	1947-70			-0.033	-0.193	0.235	-0.209	-0.029	0.324	0.912	0.054	2.304
					(0.007)	(0.119)	(0.095)	(0.089)	(0.012)	(0.281)			

can be easily be seen from the figures.

Equations 1.5 through 1.8 comprise postwar regressions. In every case, federal R and D expenditures significantly increase human capital accumulation. Cumulative births, in sharp contrast to findings for the entire period, do not significantly increase education, with the exception of equation 1.6, though again the effect on savings is insignificant. The effect of current and lagged income on schooling is more evenly distributed for the postwar era, though the joint effect is much the same. Lastly, the unemployment rate exerts the same countercyclical influence in 1.6 as in equation 1.2.

The negative and significant effect of R and D expenditures on savings in equation 1.8 is consistent with expectations. Cumulative births continue to have no effect, and current income continues to enter opposite in sign to lagged income, though the joint income coefficient (0.205) is greater than in the full sample regression.

These results suggest first, that measures of technical change raise accumulation of human capital, and lower accumulation of physical capital, consistent with expectations, though not always significantly. Second, higher unemployment raises human capital, and if anything, lowers savings in related regressions; this suggests that relative accumulation of human capital increases countercyclically. A ready interpretation of the second finding is that schooling is cheaper during periods of low expected wages. Third, the joint effect of income does not appear to affect relative accumulation.

To strengthen comparisons between the regressions, a number of equations are presented in Table 2 which use either the ratio of savings to schooling investments or else the difference between these variables in place of separate

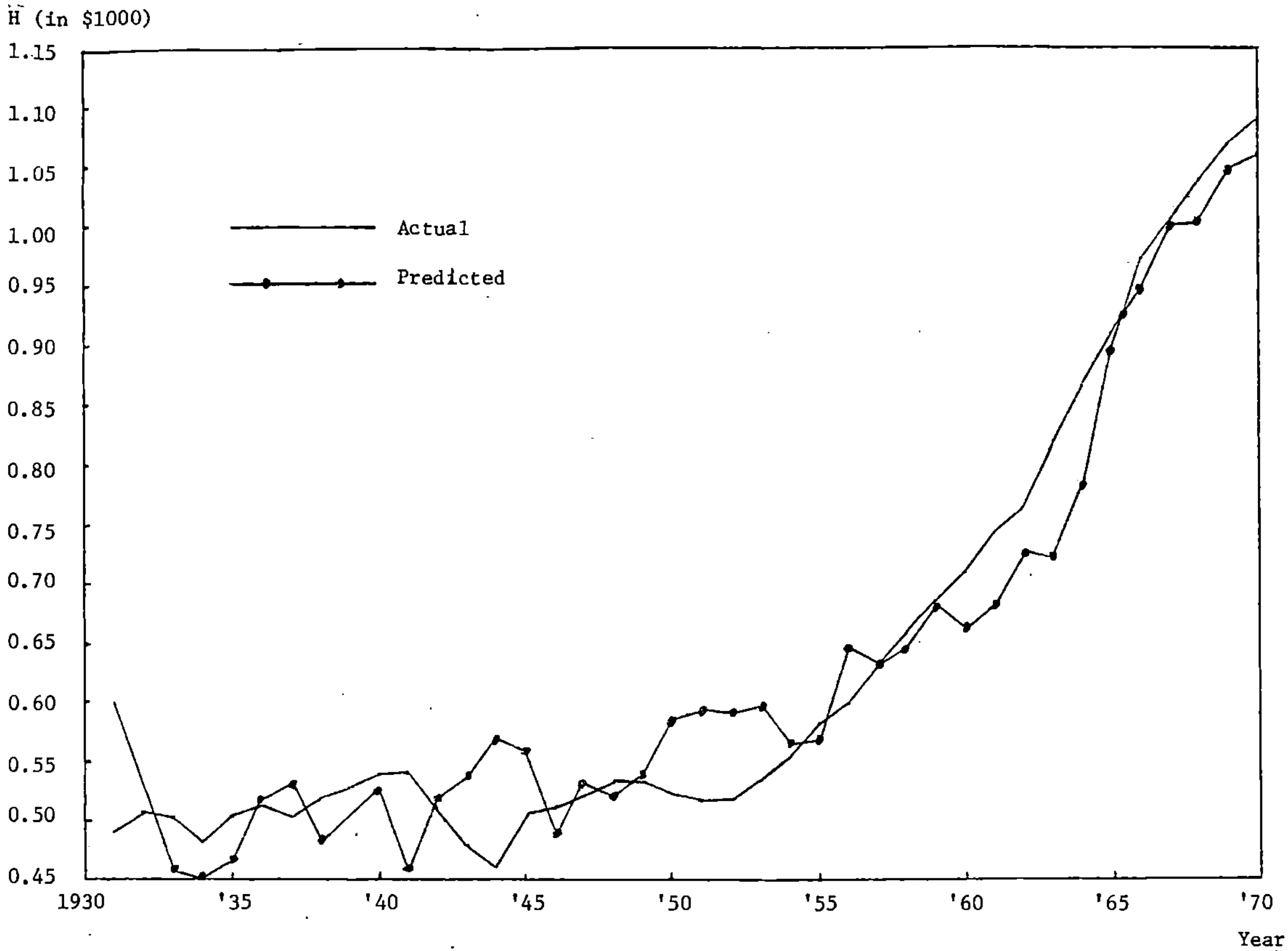

Figure 1 - Actual Versus Predicted
Educational Expenditures per Family
(in 1958 $)
Source: see text

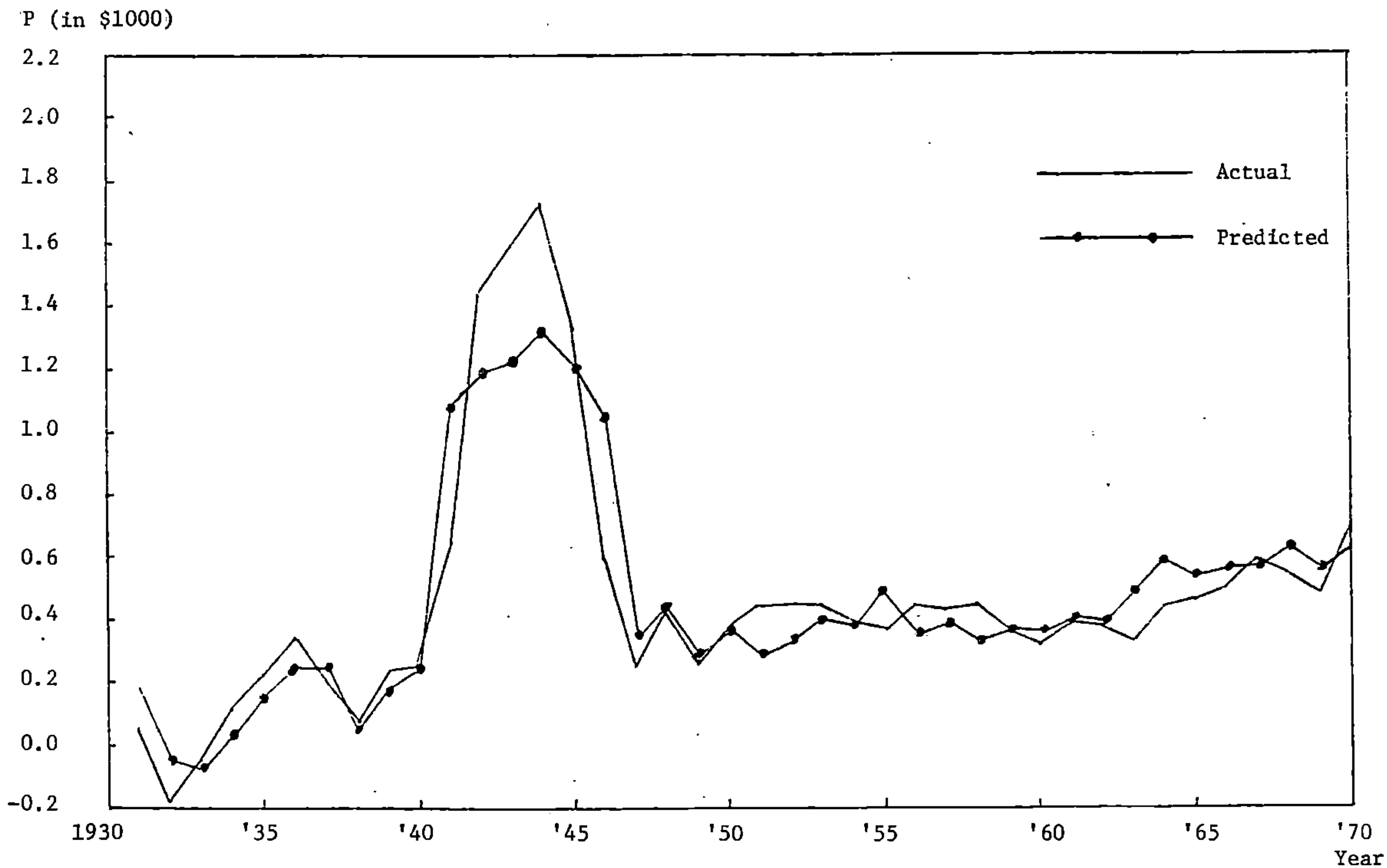

Figure 2 - Actual versus Predicted
Personal Savings per Family
(in 1958 $)
Source: see text

capital accumulation measures. Dependent variables are defined as follows: R is the ratio of savings to H, educational expenditures adjusted for unemployment; DC equals P - H, or the absolute difference; and RA and DCA are similar ratio and difference variables, replacing H with HA, or unadjusted educational expenditures.

Regressions for the entire period are shown in equation 2.1 and 2.2. Patent issuances increase schooling relative to saving; cumulative births have no effect, and war raises saving in comparison to schooling. Income is a more intricate variable. In 2.1 and 2.2 as well, the joint effect of a rise in income is insignificant; in each case, current income raises saving relative to schooling, only for the impact effect to be virtually erased by an equivalent increase in lagged income. This supports the previous observation that permanent income does not seem to affect relative accumulation for this body of data.[20/]

Results for the postwar era are summarized by equations 2.3 through 2.6. In every equation R and D expenditures lower savings in comparison to schooling, while cumulative births have no effect on relative accumulation, and the joint effect of current and lagged income remains insignificant. It is also worthwhile to note that an increase in unemployment significantly lowers relative asset accumulation, reinforcing the impression of countercyclical relative movements in schooling. In summary, the relative accumulation functions presented in Table 2 provide further support for inferences drawn from the earlier regressions.

V. Summary

A theory of optimal composition of family wealth in human capital and assets developed in this paper suggests that relative human capital accumulation increases with the rate of innovation. This implication, which suggests that even apparently neutral economic growth can have non-neutral effects on wealth composition, was borne out by an empirical analysis of aggregate time series for the United States. Other findings are that relative accumulation of human capital appears to follow a countercyclical pattern, while neither family income nor cumulative births affect relative capital accummulation. The principal implication seems to be supported by the evidence presented in the paper.

Footnotes

1/ One could assume that human capital is productive only in the sense that it provides information about workers to prospective employers, as in the Screening Hypothesis. Wolpin (1977) provides new evidence which suggests that the screening function of education and other human capital is relatively unimportant, however.

2/ See for example Becker (1974) and Adams (1976).

3/ This approach amounts to collapsing the future into a single period of time; it is conducive to an adaptive expectations assumption in an empirical analysis.

4/ Technically, U_j is a separable utility function as in Gorman (1959) and Strotz (1957, 1959).

5/ All quantities are of course present values. For example, C^*_{j+1} is the present value of the next generation's expenditures, hence $C^*_{j+1} = W_{j+1}$.

6/ The definition of marginal costs is $MC_h = P_h + h_{j+1} \frac{dP_h}{dh_{j+1}}$.

7/ Notice that this model allows partial overlap of the working lives of the two generations. Reverting to annual accounting periods, and letting ρ = annual rate of interest,

$$W_j = \sum_{i=0}^{N} \frac{Y_{ij}}{(1+\rho)^i}$$

is the wealth of the head defined in annual incomes Y_{ij}. Similarly,

$$W_{j+1} = \sum_{k=m}^{N+m} \frac{Y_{k,j+1}}{(1+\rho)^k}$$

is the wealth of the next generation defined in terms of its annual incomes $Y_{k,j+1}$. To introduce effects of growth, assume that beyond period ℓ all incomes rise in the proportion g. Then the change in the head's wealth is

$$dW_j = \sum_{i=\ell}^{N} \frac{Y_{ij} \cdot g}{(1+\rho)^i} .$$

The change in the next generation's wealth is

$$dW_{j+1} = \begin{cases} \sum_{k=m}^{N+m} \dfrac{Y_{k,j+1}g}{(1+\rho)^k}, & \text{if } m > \ell \\[2ex] \sum_{k=\ell}^{N+m} \dfrac{Y_{k,j+1}g}{(1+\rho)^k}, & \text{if } m < \ell \end{cases}$$

The percentage changes are

$$\frac{dW_j}{W_j} = g - \sum_{i=0}^{\ell-1} \frac{Y_{ij}}{(1+\rho)^i} \Big/ W_j = g - r_j$$

and

$$\frac{dW_{j+1}}{W_{j+1}} = \begin{cases} g \text{ if } & m > \ell \\ g - \sum_{k=m}^{-1} \dfrac{Y_{k,j+1}}{(1+\rho)^k} \Big/ W_{j+1} = g - r_{j+1} \end{cases}$$

It would seem that $r_{j+1} < r_j$ and $dW_j/W_j < dW_{j+1}/W_{j+1}$, since $\ell-1 > \ell-m-1$ and $Y_{ij}/(1+\rho)^i W_j > Y_{k,j+1}/(1+\rho)^k W_{j+1}$ on average; i.e., growth raises income for the next generation for more years and years of higher earnings than for the head.

8/ It is presumed that for a very small human capital transfer the marginal cost is less than the price of a unit of assets. While there is no theory which would predict this, it seems a reasonable presumption.

9/ Consider the production function at time t,

$$Q(t) = A(t) f[K(t), h(t) \cdot L(t)],$$

where A(t) is an index of technology which is factor neutral, K(t) is physical capital, h(t) is human capital per worker, and L(t) is raw labor. Following Nelson and Phelps (1964) I specify

$$A(t) = A_o e^{g[t - \ell(h)]}$$

so that the level of technology depends on the rate of technical change g and the lag in its application. The lag in application in turn depends negatively on human capital intensity, so $\ell'(h) < 0$. The marginal product of h is

$$\frac{\partial Q(t)}{\partial h} = - \ell'(h)\ g\ Q(t) + \frac{\partial Q(t)}{\partial [h(t)l(t)]}\ L(t);$$

clearly it increases with the rate of technical change.

10/ Interest rate effects are ignored in the sequel. Entry of the real corporate bond rate in the regressions failed to yield significant results in the preliminary work.

11/ The average share of human capital in transfers is

$$\alpha_h = \gamma_h + (1-\gamma_h)\ \beta_h,$$

where γ_h is the share of families leaving only human capital in all transfers, $1-\gamma_h$ is the share of families leaving partly assets in all transfers, and $0 < \beta_h < 1$ is the share of human capital in the transfers of the latter families. Then, where g is the growth rate,

$$\frac{d\alpha_h}{dg} = (1 - \gamma_h)\ \frac{d\beta_h}{dg} > 0 \quad \text{if } \frac{d\beta_h}{dg} > 0,$$

assuming a constant distributional weight, γ_h.

12/ According to footnote 7, Θ is likely to be less than one. If Θ were zero, as in a model with no overlap of working lives of the two generations, the conclusion would be guaranteed. A factor in favor of this interpretation is that present innovations may require many years to begin yielding returns.

13/ Per family transfers could increase if growth raised family size (Becker and Tomes, 1976). However, growth raises wages and may raise the relative costs of children. It is clearly not essential that family size and indirectly, population growth rise with the rate of economic growth, since the rise in implicit costs could lower family size.

14/ More details can be found in Schultz (1971), Ch. 8. The assumption of 0, 11, and 25 weeks equivalent loss in foregone earnings is based on the year 1949. The author performed similar calculations for 1969 and found virtually no change in weeks equivalent foregone.

15/ See Appendix B for further details. One variant of educational expenditures (H) adjusts foregone earnings downward by one minus the unemployment rate, corrected according to Darby (1976). This is the variant shown in Chart 1.

16/ I am indebted to Larry Kenny for this suggestion.

17/ Appendix B describes the derivation of nominal expenditures and the method of deflation in greater detail. Sample means are for H, 0.637; for HA, 0.655; for DH, 0.364; and for P, 0.468. The mean for DH is approximately 50% of mean total expenditures, which is consistent with other estimates of the importance of direct costs, and the ratio of total expenditures exceeds savings which is consistent with findings mentioned by Sahota (1978), p. 14.

18/ In postwar regressions using NPATS, patent issuances are insignificant in all regressions and hence omitted.

19/ The unemployment rate causes multicollinearity in the P equation, since all variable except W become insignificant, even though the fraction of variance explained is sizable. UNEMP has a negative effect on P in these regressions.

20/ Once again, introduction of the unemployment rate causes multicollinearity in HA and DCA regressions for the entire period, which are therefore not reported.

Appendix A

The purpose of this Appendix is to provide mathematical proof of the propositions of Section II.C. Let us assume for concreteness that an interior solution for asset transfers is attained; the analysis for the case of pure human capital transfers is a straightforward modification of this case.

The displacement system corresponding to equations (6), (7), (9), (10), and (11) (the case of positive asset transfers) is

$$\begin{bmatrix} U_{C_jC_j} & U_{C_j\bar{C}_j} & U_{C_jn_{j+1}} & U_{C_jC^*_{j+1}} & -1 \\ U_{\bar{C}_jC_j} & U_{\bar{C}_j\bar{C}_j} & U_{\bar{C}_jn_{j+1}} & U_{\bar{C}_jC^*_{j+1}} & -\frac{1}{1+r} \\ U_{C^*_{j+1}C_j} & U_{C^*_{j+1}\bar{C}_j} & U_{C^*_{j+1}C^*_{j+1}} & U_{C^*_{j+1}n_{j+1}}-\lambda P_a & -P_an_{j+1} \\ U_{n_{j+1}C_j} & U_{n_{j+1}\bar{C}_j} & U_{n_{j+1}C^*_{j+1}}-\lambda P_a & U_{n_{j+1}n_{j+1}} & -g_{j+1} \\ -1 & -\frac{1}{1+r} & -P_an_{j+1} & -g_{j+1} & 0 \end{bmatrix} \begin{bmatrix} dC_j \\ d\bar{C}_j \\ dC^*_{j+1} \\ dn_{j+1} \\ d\lambda \end{bmatrix} =$$

$$\begin{bmatrix} 0 \\ -\frac{\lambda}{(1+r)^2}\,dr \\ 0 \\ 0 \\ \frac{-d\bar{Y}_j}{(1+r)} + \frac{\bar{Y}_j}{(1+r)^2}\,dr - P_an_{j+1}de_{j+1} \end{bmatrix}, \qquad \text{(A.1)}$$

where relative price effects of growth are assumed to have been worked out, leaving only interest rate and wealth effects. On the right-hand side of (A.1), increments in the head's wealth are written as $\frac{d\overline{Y}_j}{1+r}$, where $W_j = Y_j + \frac{\overline{Y}_j}{1+r}$ and $\overline{Y}_j$ is the head's future income. Assuming interest rate effects to be insignificant, and letting g = rate of economic growth, wealth effects on the next generation's per capita consumption are:

$$\frac{\partial C^*_{j+1}}{\partial g} = \frac{\partial C^*_{j+1}}{\partial W_j} \left(\frac{\partial \overline{Y}_j}{\partial g} \frac{1}{1+r} + P_a n_{j+1} \frac{\partial e_{j+1}}{\partial g}\right). \qquad (A.2)$$

since net transfers $t_{j+1} = C^*_{j+1} - e_{j+1}$, the effect on the level of transfers is

$$\frac{\partial t_{j+1}}{\partial g} = \frac{\partial C^*_{j+1}}{\partial g} - \frac{\partial e_{j+1}}{\partial g}$$

$$= \frac{\partial C^*_{j+1}}{\partial SW_j} (1+\Theta)\ P_a n_{j+1} - 1 \quad \frac{\partial e_{j+1}}{\partial g}, \qquad (A.3)$$

where $\frac{\partial \overline{Y}_j}{\partial g} \frac{1}{1+r} = \Theta\ P_a n_{j+1} \frac{\partial e_{j+1}}{\partial g}$, $\Theta \geq 0$. If $\Theta = 0$, $\frac{\partial t_{j+1}}{\partial g} < 0$, because

$$\frac{\partial C^*_{j+1}}{\partial g} \quad \overline{Y}_j = \frac{\partial C^*_{j+1}}{\partial W_j} \ P_a n_{j+1} \frac{\partial e_{j+1}}{\partial g} \qquad (A.4)$$

would then be the marginal propensity to consume C^*_{j+1}, which is less than $\frac{\partial e_{j+1}}{\partial g}$, the increase in wealth, if other consumption is normal. Since $0 \leq \Theta \leq 1$ for reasons given in the text, the expression in (A.4) could be less than one and yet $\frac{\partial t_{j+1}}{\partial g} \leq 0$. Clearly also

$$\frac{\partial n_{j+1}}{\partial g} = \frac{\partial n_{j+1}}{\partial W_j} \ (1+\Theta)\ P_a n_{j+1} \ \frac{\partial e_{j+1}}{\partial g}, \qquad (A.5)$$

which is positive provided $\frac{\partial n_{j+1}}{\partial W_j} > 0$.

Appendix B

Data Sources and Methods of Construction

Directly transcribed series primarily came from Historical Statistics of the United States from Colonial Times to 1970 (U.S. Department of Commerce, 1975). Number of patents issued (NPATS) is series W99; Federal Research and Development Expenditures (FRD) is series W126, deflated by the implicit GNP deflator, series F5; the rate of unemployment (UNEMP) is series D86 for the years 1970-1944, adjusted according to Darby (1976) for the years 1943-1930; savings per family (P) and Disposable Personal Income per family (YPF) are series F552 and F9 respectively, divided by the number of family units, series A350.

Cumulative birth rates of women aged 45-49 (BCUML) can be found in Vital Statistics of the United States, Vol. 1, Natality, Section 1, Rates and Characteristics, Public Health Service, (U.S. Department of Health, Education and Welfare, various years) and Vital Statistics of the United States - Special Reports, Vol. 51, No. 1, Fertility Tables for Birth Cohorts of American Women (Whelpton and Campbell, 1960).

The description of the method by which real educational expenditures per family (H or HA) are constructed remains. Nominal educational expenditures for the United States are calculated as the sum of estimated direct expenditures and foregone earnings for all students. For higher education, total annual expenditures of Institutions (U.S. Department of Commerce, 1975), series H728, are reduced to net expenditures on college and high school students by deducting expenditures on Auxiliary Enterprises, series H737, and adding in implicit interest and depreciation on the value of plant, series H747, estimated at 8%. The net (biennial) series is then linearly interpolated for odd-numbered years. Similarly, net direct expenditures for private and public elementary and secondary schools are derived by the addition of implicit interest and depreciation to total annual expenditures series H492, and deducting capital outlays, series H499. The estimated net annual expenditures are then summed.

The foregone earnings of college and university and high school students are estimated assuming that the former give up the equivalent of 25 weeks' average earnings in manufacturing and the latter 11 weeks, as in Schultz (1971). Total foregone earnings of college and university students are then computed as 25 times mean weekly earnings in manufacturing, series D804, times college and university enrollments, series H700. Total foregone earnings of high school students are then approximated by 11 times mean weekly earnings in manufacturing times high school enrollments, series H412-432. This biennial series is again interpolated for odd-numbered years.

The sum of the two series is estimated nominal educational expenditures for the United States annually. In the case of the derived series of total educational expenditures per family adjusted for unemployment (H), expenditures are the sum of direct expenditures, plus foregone earnings times one minus the adult unemployment rate, all deflated by a comprehensive educational cost index and divided by the number of family units, series A350.

The educational cost index is calculated using weights for foregone earnings, maintenance of plant at all levels of schooling, salaries of college and university personnel, salaries of public and private elementary and secondary school employees, and foregone earnings of students. Weights were then multiplied in order by these price series, and summed to yield the index: the Composite Cost Index of the U.S. Department of Commerce, found in <u>Construction Review</u> (U.S. Department of Commerce, various years); average annual salaries of college teachers, series D913 of <u>Historical Statistics</u>;

average annual earnings of public employees, series D763; and average weekly earnings in manufacturing, series D804.

Real educational expenditures per family not adjusted for unemployment (HA) are simply the total nominal expenditures divided by the above cost index and the number of family units. Direct educational expenditures per family (DH) are total nominal direct expenditures divided by a cost index omitting foregone earnings, with weights adjusted to sum to unity, and divided by the number of family units.

References

Adams, J.D. "A Theory of Intergenerational Transfers," unpublished Ph.D. dissertation, University of Chicago, 1976.

Becker, G.S. Human Capital and the Personal Distribution of Income: An Analytical Approach. Ann Arbor, Michigan, Institute for Public Administration, University of Michigan, 1967.

______ "A Theory of Social Interactions." J.P.E. 82 (November/December 1974): 1063-1093.

Becker, G.S. and Lewis, H.G. "On the Interaction between Quantity and Quality of Children." J.P.E. 84 (August 1976): S143-S162.

Becker, G.S. and Tomes, N. "Child Endowments and the Quantity and Quality of children." J.P.E. 82 (March/April 1973): S279-S288.

Blinder, A.S. "Intergenerational Transfers and Life Cycle Consumption." A.E.R. 66 (May 1976): 87-93.

Darby, M. "Three and a Half Million U.S. Employees Have Been Mislaid: Or an Explanation of Unemployment, 1934-1941." J.P.E. 84 (February 1976): 1-16.

Gorman, W.M. "Separable Utility and Aggregation." Econometrica 27 (July 1959): 469-481.

Houthakker, H.S. "Compensated Changes in Quantities and Qualities Consumed." Re. Stud. 19, No. 3 (1952): 155-164.

Nelson, R.R. and Phelps, E.S. "Investment in Humans, Technological Diffusion, and Economic Growth." A.E.R. 54 (May 1964): 69-75.

Sahota, G.S. "Theories of Personal Income Distribution." J.E.L. 16 (March 1978): 1-15.

Strotz, R.H. "The Empirical Implications of the Utility Tree." Econometrica 25 (April 1957): 269-280.

______ "The Utility Tree - A Correction and Further Appraisal." Econometrica 27 (July 1959): 482-488.

Samuelson, P.A. "A Theory of Induced Innovation Along Kennedy-Weisacker Lines." Re. Stat. 47 (November 1965): 343-355.

Schmookler, J. "Comment on 'Some Difficulties of Measuring Inventive Activity'" in The Rate and Direction of Inventive Activity, ed. R.R. Nelson. Princeton, New Jersey: Princeton University Press for N.B.E.R., 1962.

______ Invention and Economic Growth. Cambridge, Massachusetts: Harvard University Press, 1966.

Schultz, T.W. Investment in Human Capital. New York: The Free Press, 1971.

_______ "The Value of Ability to Deal with Disequilibria." J.E.L. 13 (September 1975): 827-846.

U.S. Department of Commerce. Construction Review, Washington, D.C.: U.S. Government Printing Office, various issues.

U.S. Department of Commerce, Bureau of the Census. Historical Statistics of the United States: Colonial Times to 1970. Washington, D.C. : U.S. Government Printing Office, 1975.

U.S. Department of Health, Education, and Welfare. Vital Statistics of the United States, Vol. 1, Natality, Section 1, Rates and Characteristics. Washington, D.C.: U.S. Government Printing Office, various years.

U.S. Department of Health, Education, and Welfare. Vital Statistics of the United States, Special Reports, Vol. 51, No. 1, "Fertility Tables for Birth Cohorts of American Women" by Pascal K. Whelpton and Arthur A. Campbell. Washington, D.C.: U.S. Government Printing Office, 1960.

Wolpin, K., "Education and Screening," A.E.R. 67 (December 1977): 949-958.